Ultra-broadband Wireless Communications Systems Development

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Outline

- Motivation
- Progress
  - Ultra-broadband transmitter
  - Ultra-broadband detector
- Conclusion & future work

Motivation – Towards high-capacity communications

- Growing demand for high-capacity wireless links

<u>Shannon's theorem</u>

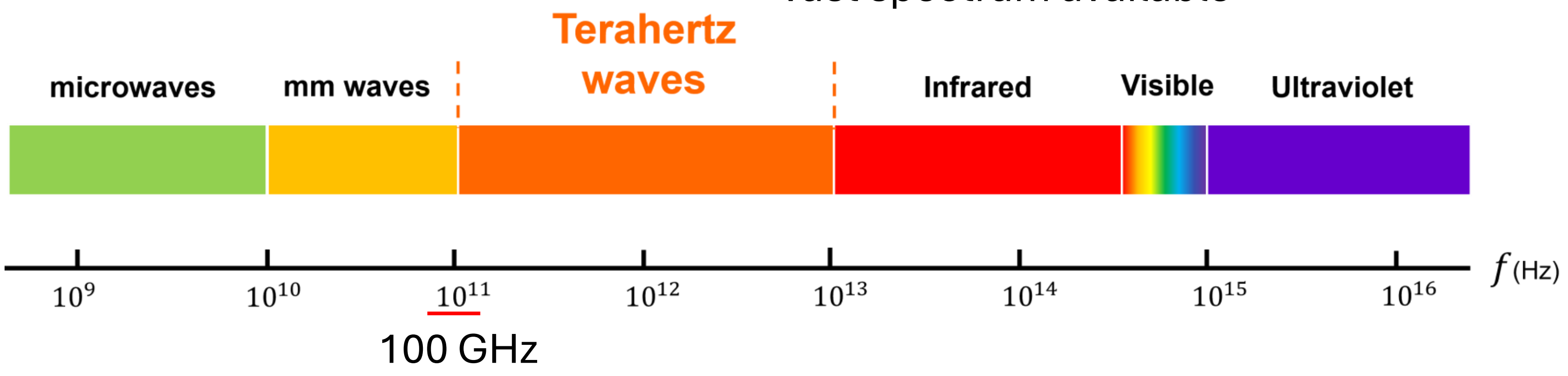
$$C = B \log_2(1 + S/N)$$

C : Channel Capacity
B : Bandwidth of transmission line
S/N : Signal to Noise Ratio

→

- Wider bandwidth (*B*)
- High carrier frequencies

vast spectrum available

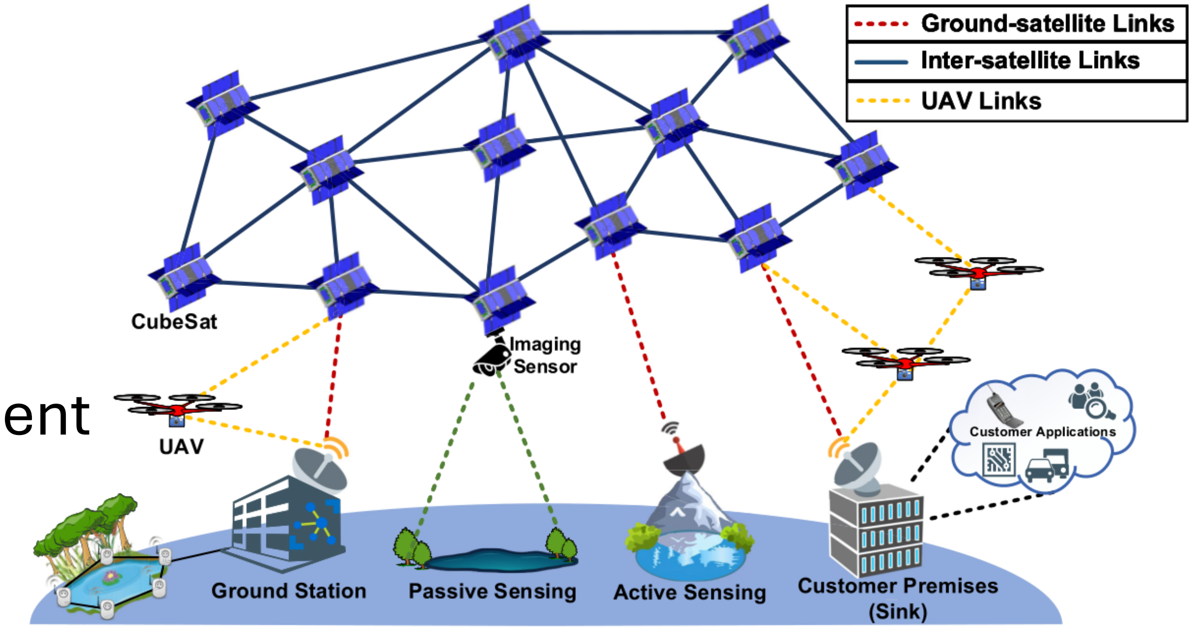


Motivation – Towards high-capacity communications

Inter-satellite links

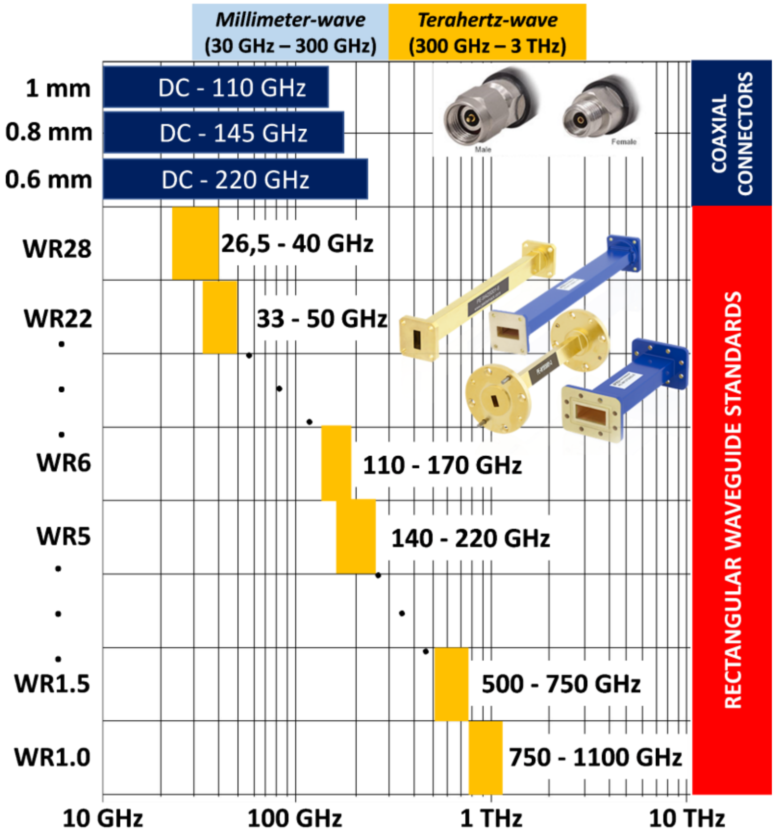
Ka band: 26 – 40 GHz

- Large observation data
- Negligible atmospheric attenuation
- Compact antennas
- No stringent requirements for beam alignment
- Can be applied to sensing/imaging

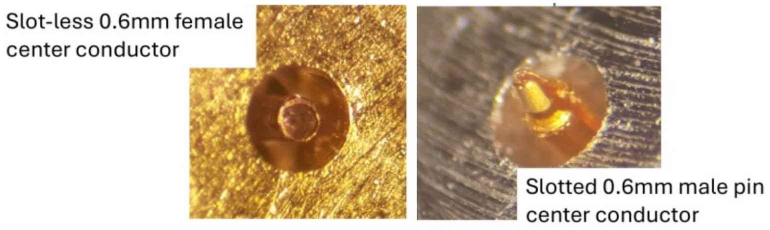


Technical challenge – Signal extraction / delivery

▶ Interconnections / Integration

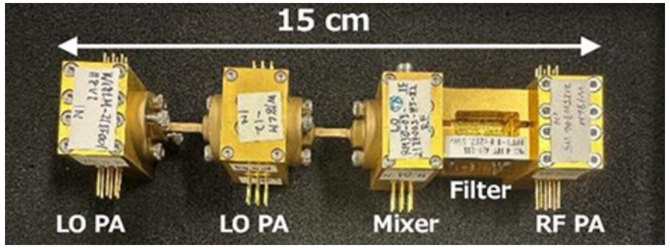


Coaxial connectors



- Fragile
- Need technicians
- High loss

Rectangular waveguides



- Bulky
- Expensive
- Limited bandwidth

Silicon dielectric waveguides

Silicon wafer

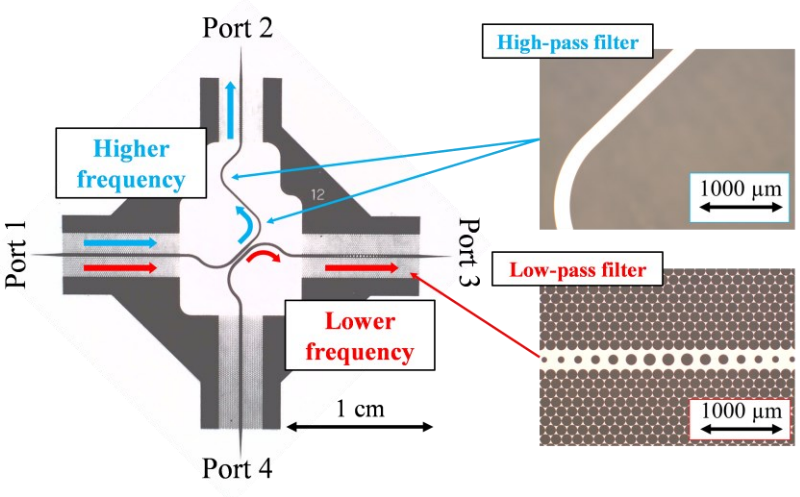
Etching process

Dielectric rod waveguides

- Low loss (0.06 dB/cm @ 300 GHz)
- Broadband (50 – 500 GHz)
- Low cost
- Versatile (Functional devices)

High-frequency Interconnections
(50 – 500 GHz)

Passive components



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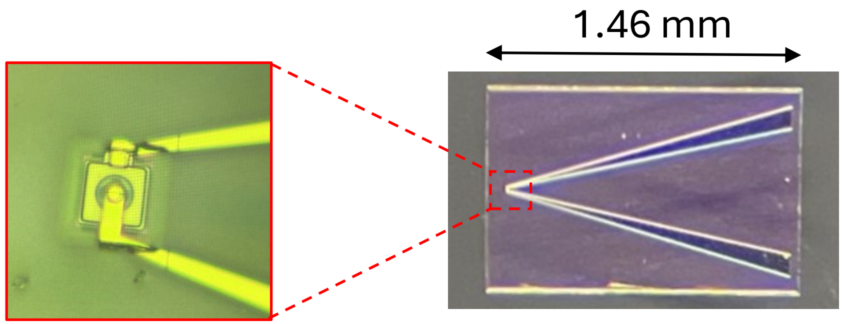
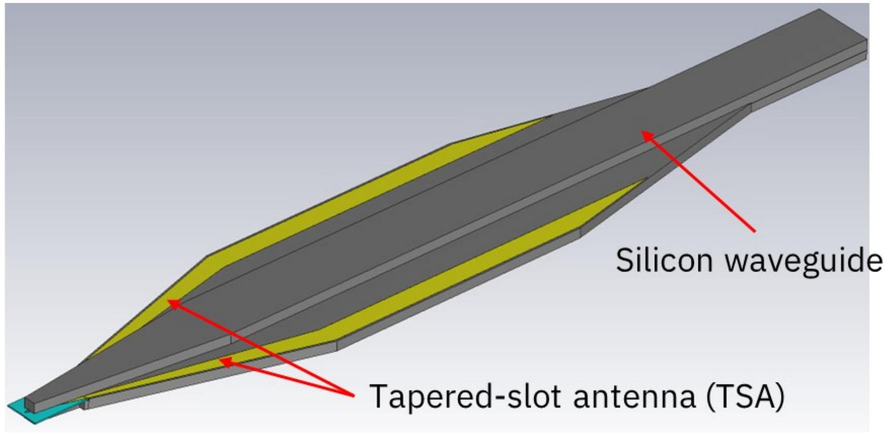
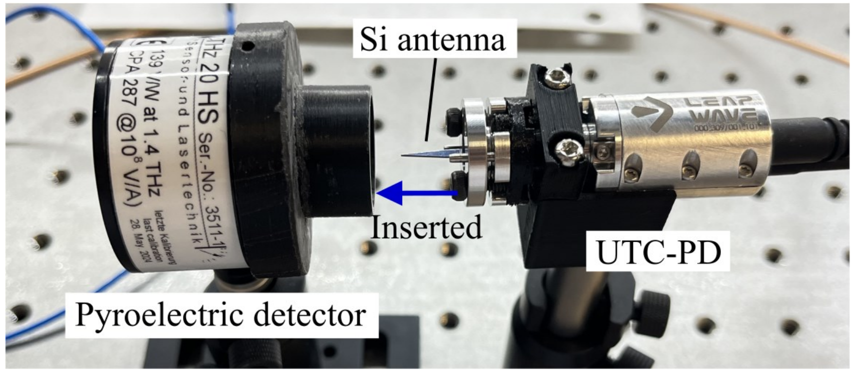
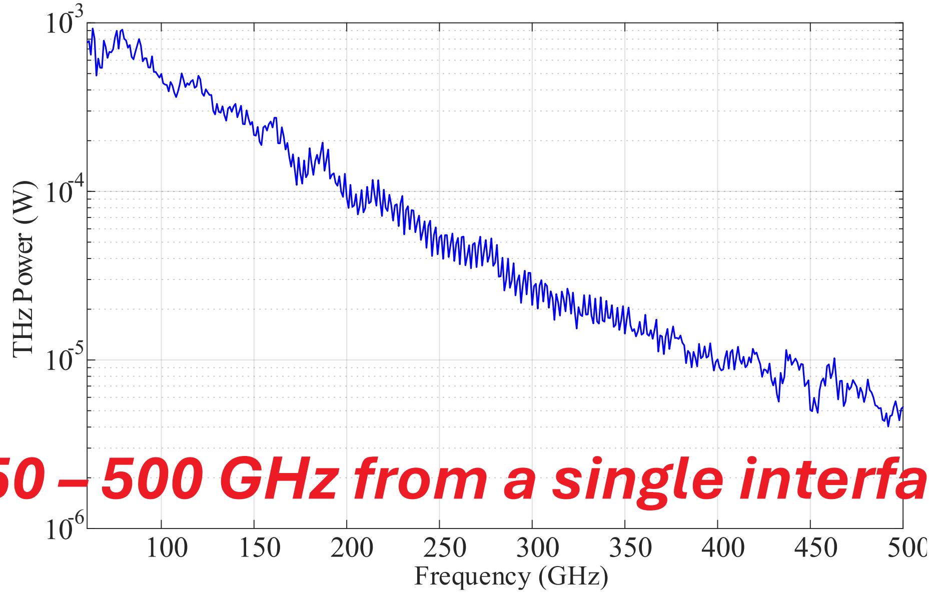
Progress – Ultra-broadband transmitter

- High-speed photodiode





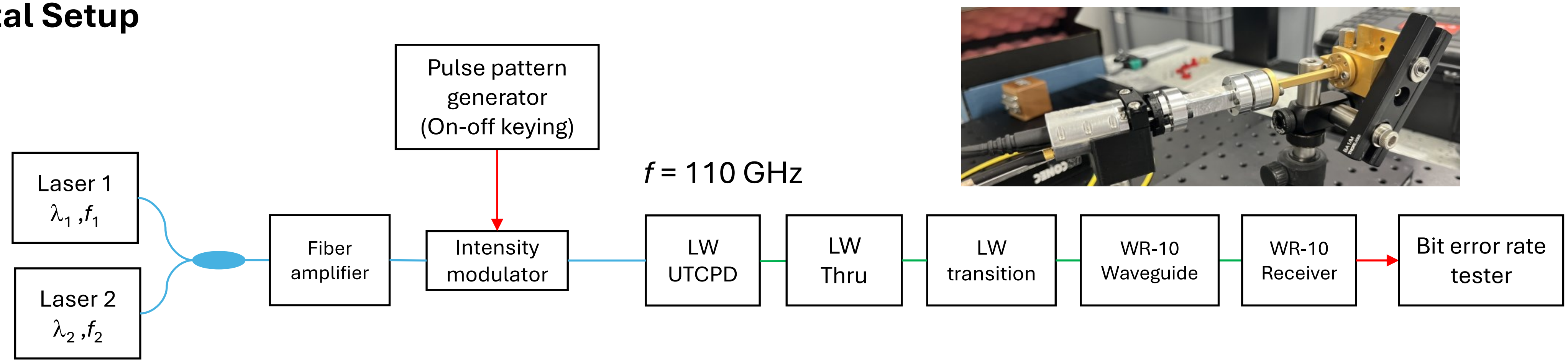




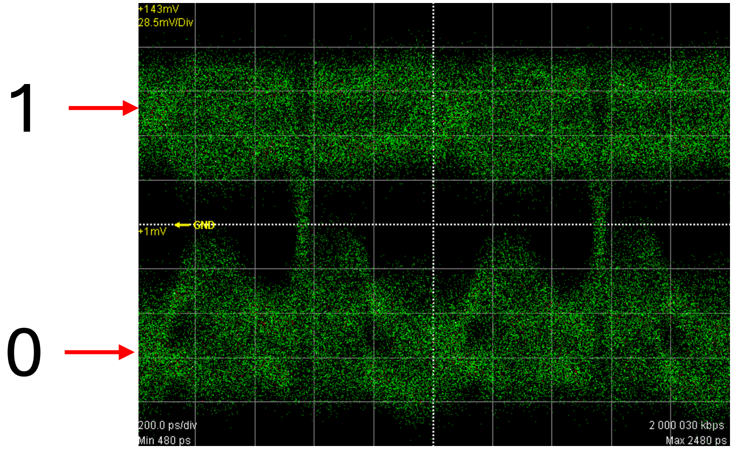
50 – 500 GHz from a single interface

Progress – Ultra-broadband transmitter

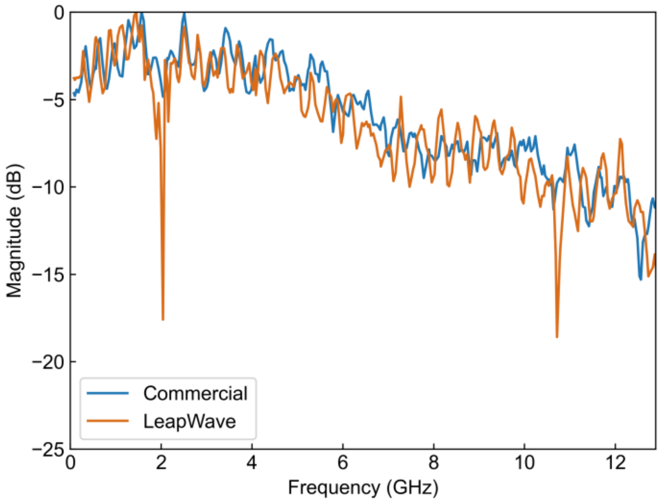
Experimental Setup



Eye diagram @ 1 Gbit/s

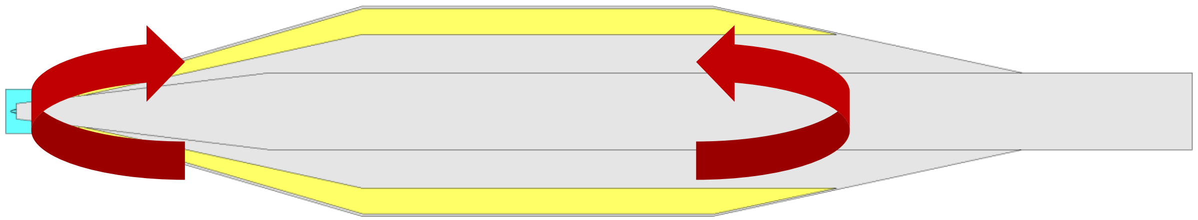


Spectral response of the system



Progress – Ultra-broadband transmitter

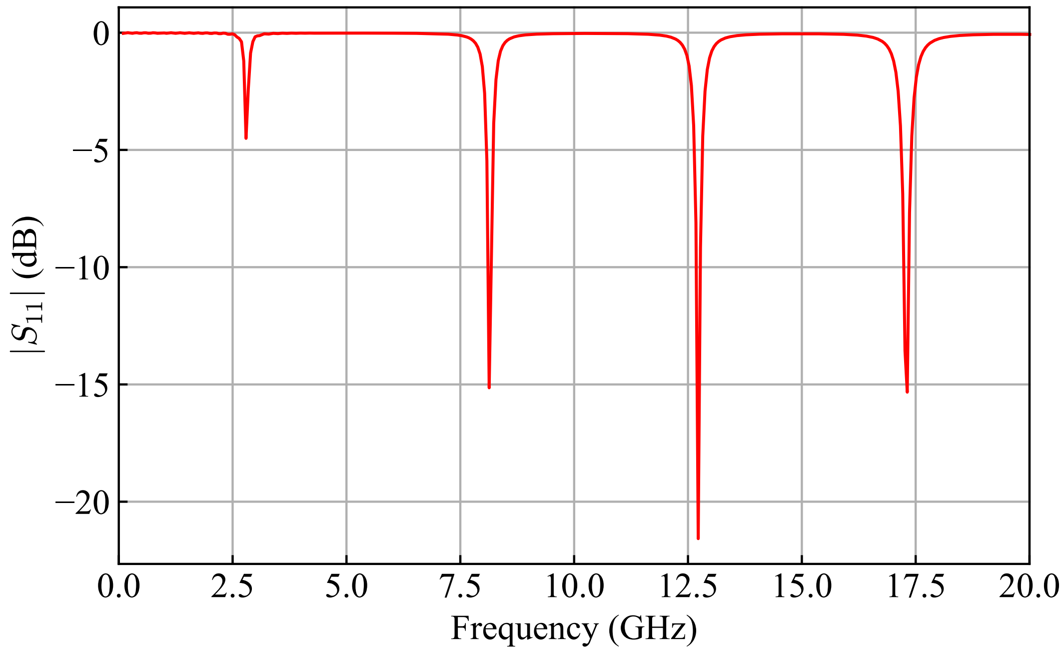
Low-frequency resonance



Two reflection points

- Diode (unmatched for broadband operation)
- Open-ended transmission line

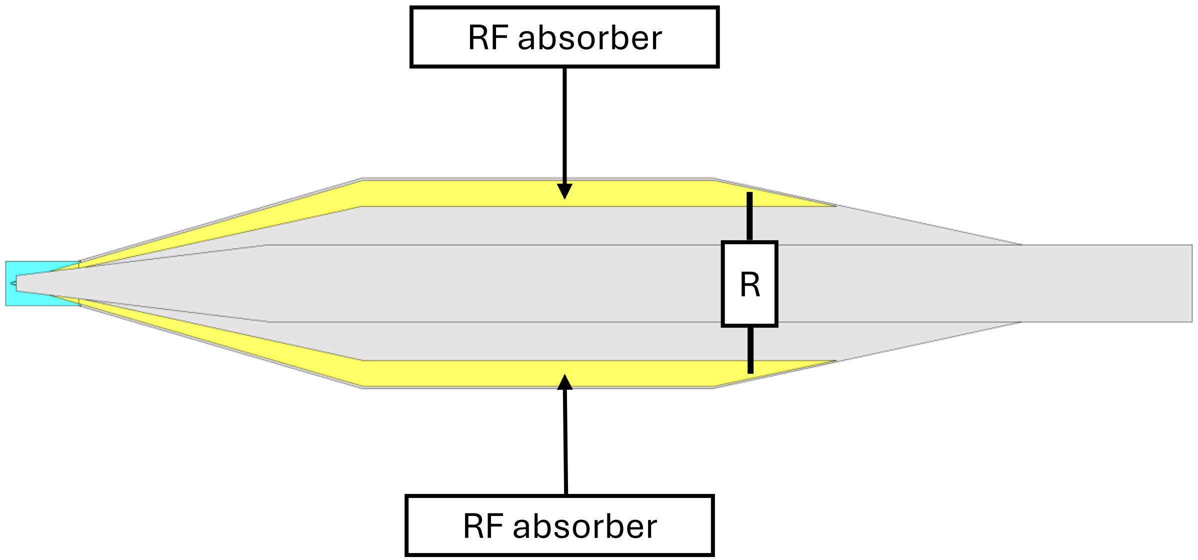
Simulation results



Confirmed the similar resonances

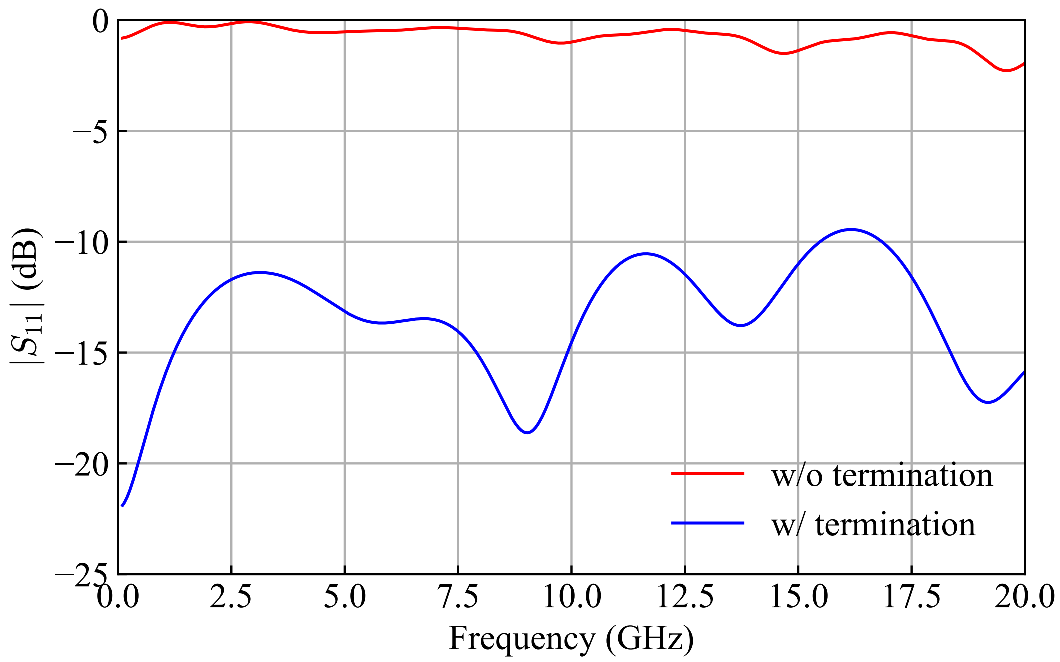
Progress – Ultra-broadband transmitter

Low-frequency termination



- Resistor: 0 ~15 GHz
- RF absorber: > 15 GHz

Simulation results



Reduced reflection -> Eliminate the resonance

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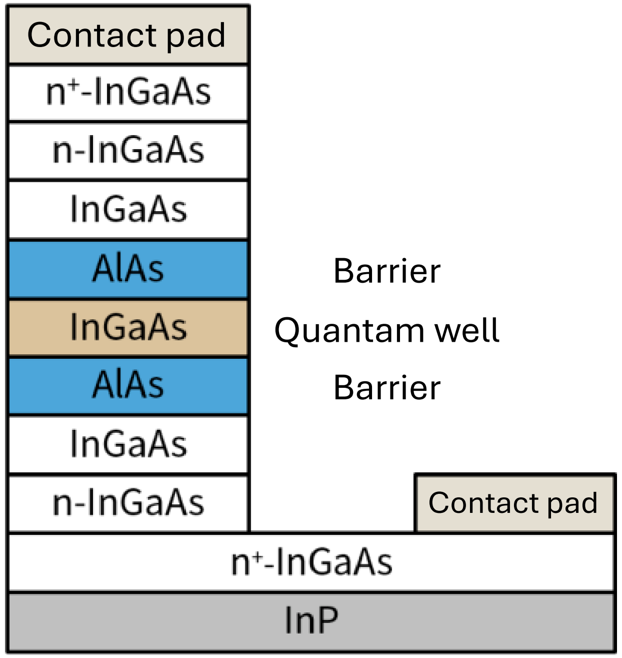
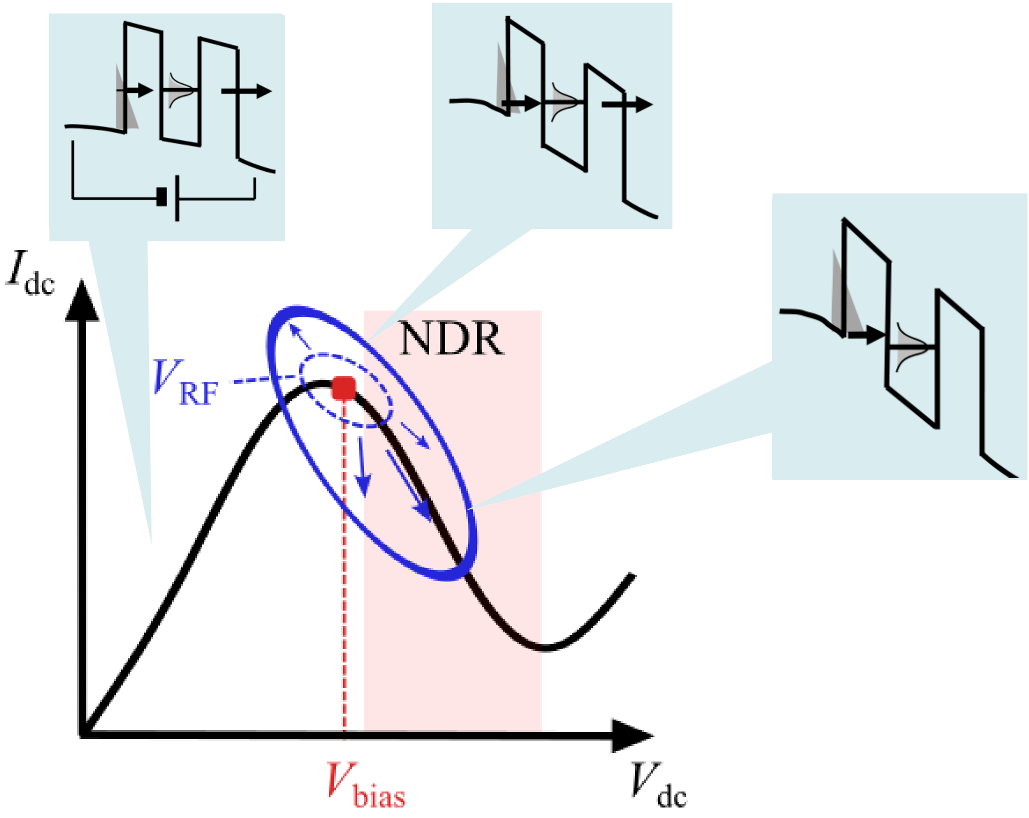
Progress – Ultra-broadband detector

▶ Terahertz resonant tunneling diode (RTD)



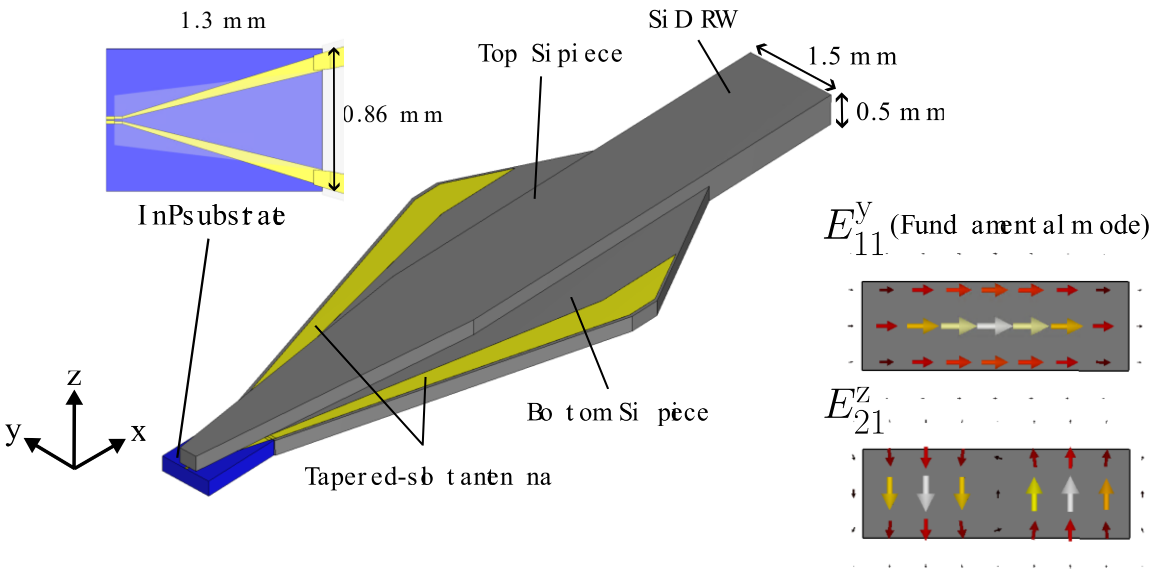


Negative differential resistance (NDR) region

- Oscillator (with resonant circuit)
- High responsivity receiver

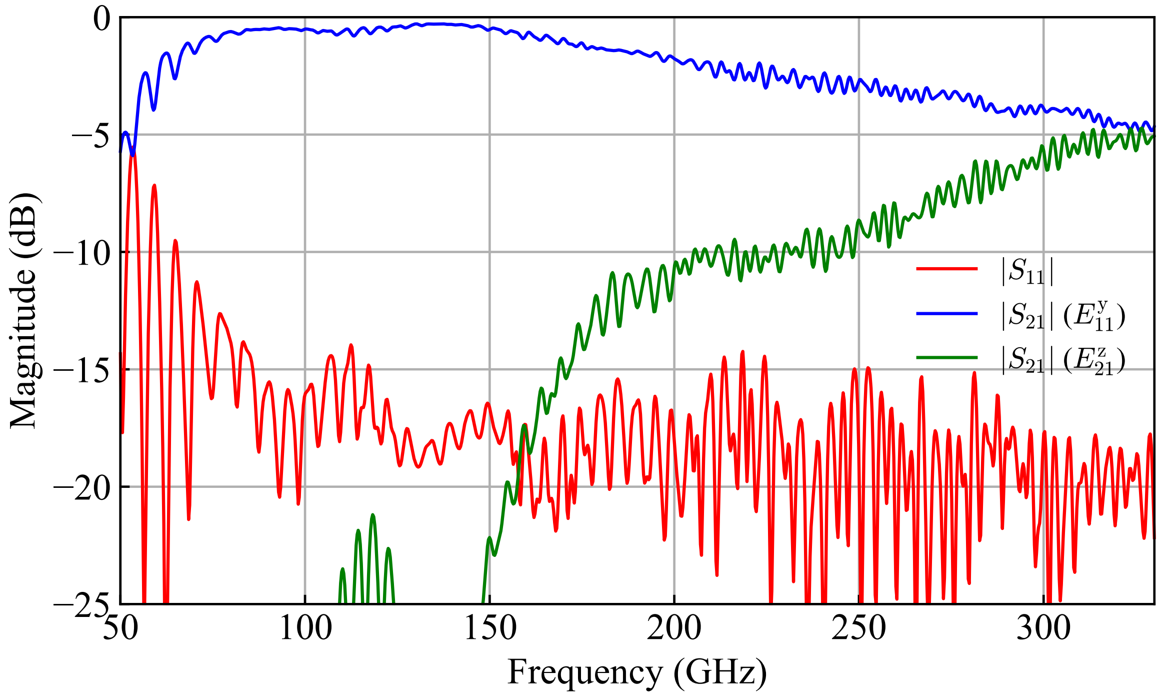
Progress – Ultra-broadband detector

Terahertz resonant tunneling diode (RTD)



- RTD on a 0.25 mm-thick InP substrate
- Taper slot antenna transition structure

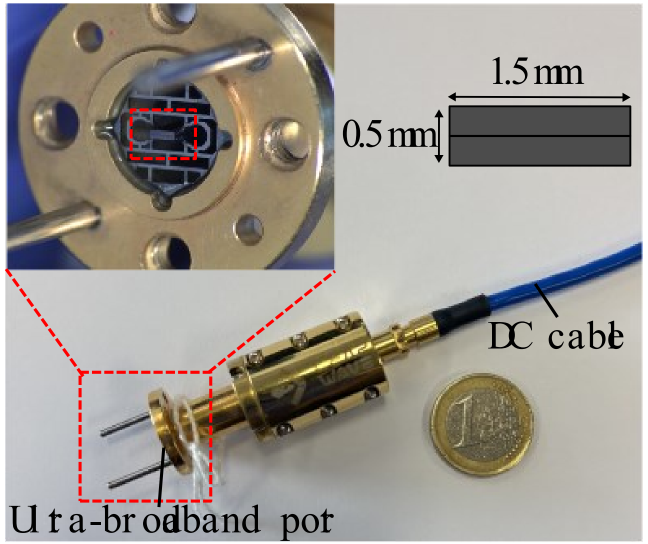
Simulation results

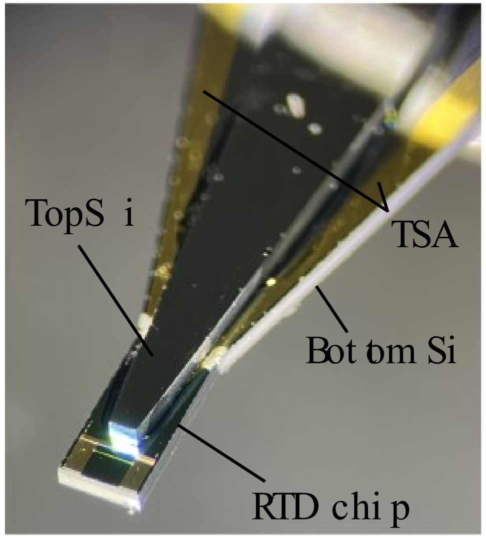


High coupling efficiency from 60 – 330 GHz for the fundamental mode

Progress – Ultra-broadband detector

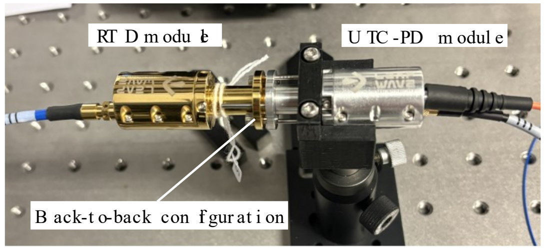
Assembly

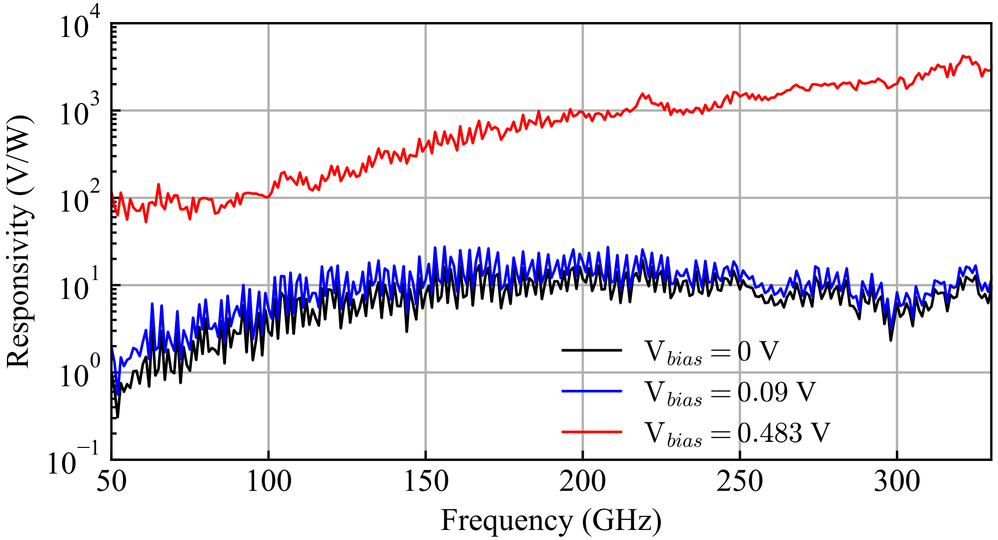




- UG387/U compatible flange
- TSAs are connected via conductive epoxy

Measurements

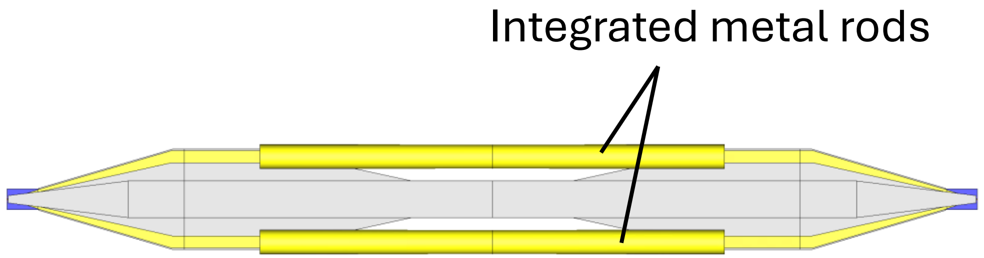




- Gain-like behavior owing to NDR
- High responsivity (Schottky barrier diode: ~ 600 V/W @ 300 GHz)

Progress – DC extension

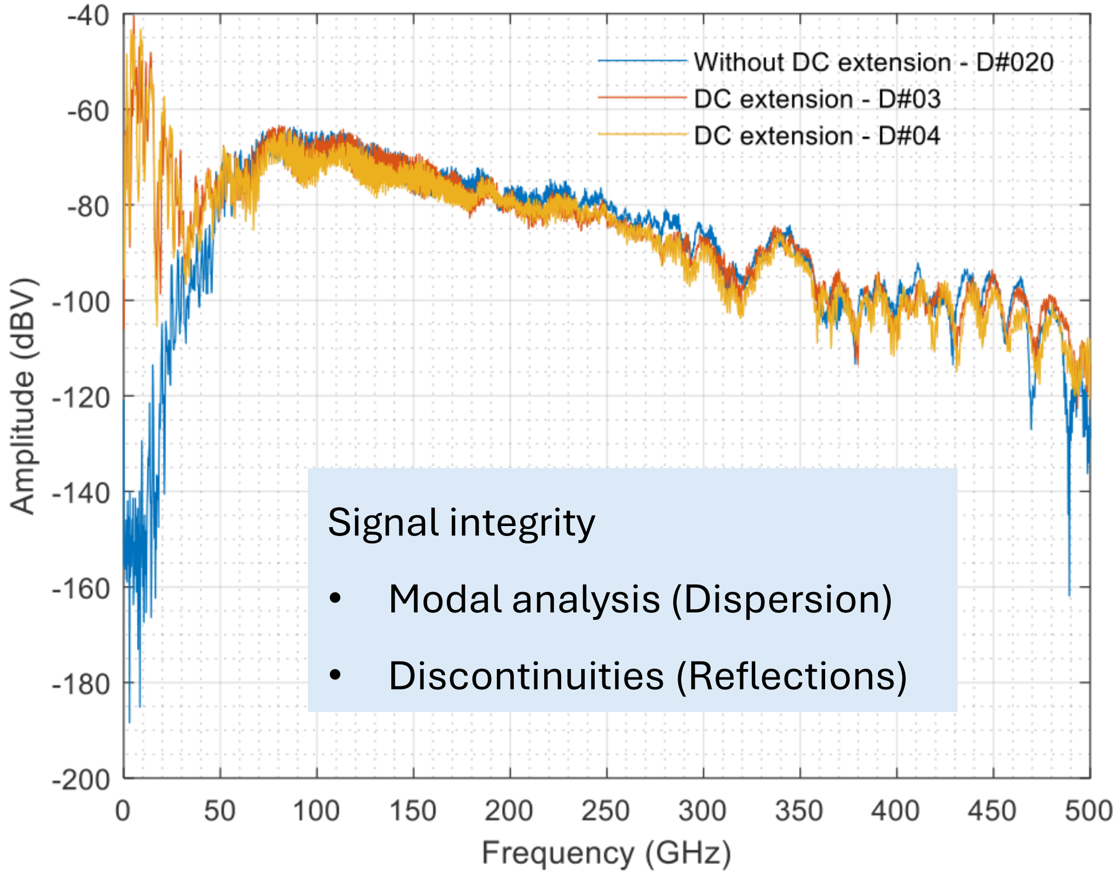
Concept



UTC-PD transmitter

RTD detector

Measurement results



Signal integrity

- Modal analysis (Dispersion)
- Discontinuities (Reflections)

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Conclusion

- The baseband resonance originates from the tapered-slot antenna (TSA) structure, and it can be suppressed by the proper termination.

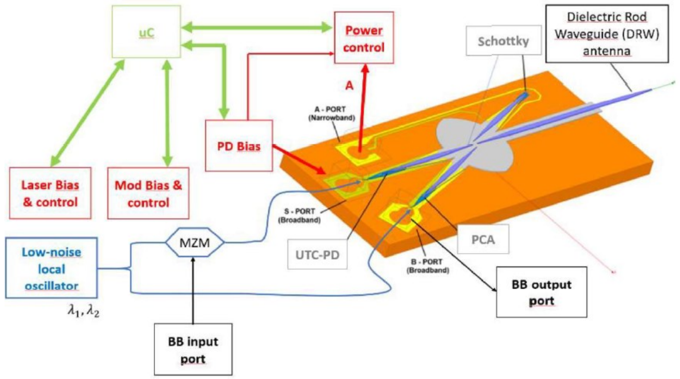
- Effective termination may be achieved using a high-frequency resistor and an RF absorber.

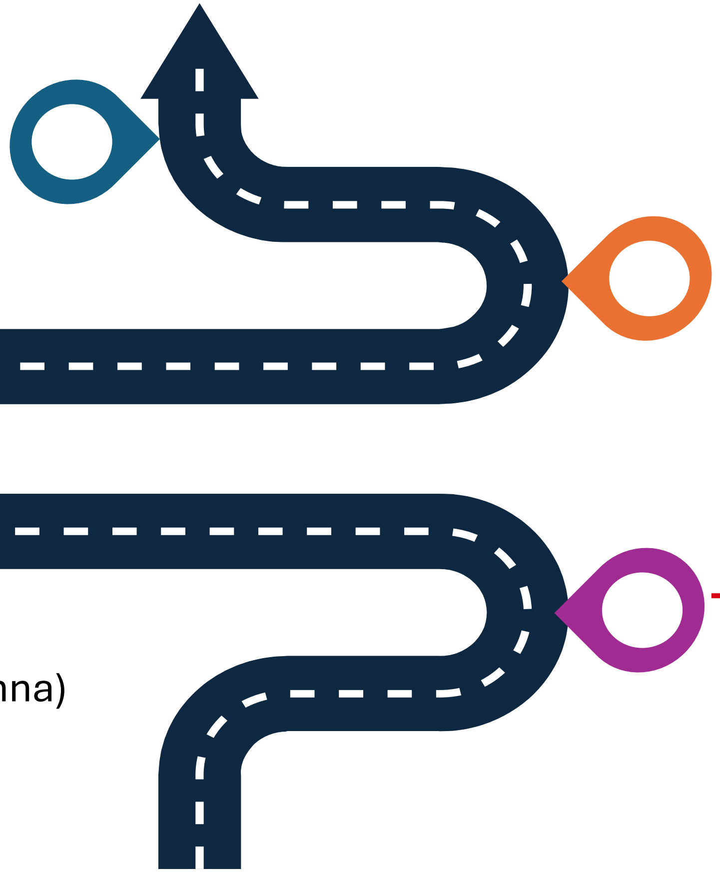
- The RTD detector exhibits high responsivity from 50 GHz to 330 GHz.

- The thick InP substrate can excite the higher order modes at higher frequencies.

- The feasibility of the DC extension was demonstrated by integrated metal rods.

Milestones of my PhD thesis





Demonstration

Other components

- ❑ Directional couplers (Designed)
- ❑ Modulators (Designed)
- ❑ Amplifiers (*Research Stay)
- ❑ DC extensions investigation

Receivers

- ✓ Initial development (RTD)
- ✓ Characterizations
- ❑ Other THz receivers (Schottky barrier diode, photoconductive antenna)

Transmitters

- ✓ Initial development
- ✓ Communication tests
- ✓ Resonance analysis
- ❑ Debug

Achievements

Activities

- Optical Design Course with Ansys ZEMAX at UC3M, 26/03/2026 – 07/05/2026, Madrid, Spain.

Conference papers

- A. Piroutiniya, M. Ali, A. Kumar, **Y. Kawamoto**, et. al, “Wideband dielectric rod antenna implemented on FR-4 substrate for THz application,’’ Proc. SPIE 13895, Terahertz, RF, Millimeter, and Submillimeter-Wave Technology and Applications XIX, 2026, https://doi.org/10.1117/12.3081055. (**Oral presentation**)
- **Y. Kawamoto,** D. Gallego, S. Gómez, T. Ishibashi, T. Nagatsuma, A. Rivera-Lavado, G. Carpintero, “Multi-octave (60-500 GHz) guided-wave terahertz source enabled by a UTC-PD on a dielectric waveguide platform,’’ MWP 2026 (**accepted**).
- **Y. Kawamoto**, D. Gallego, S. Gómez, Y. Nishida, K. Tsuruda, T. Nagatsuma, A. Rivera-Lavado, G. Carpintero, “2.7-Octave (50-330 GHz) Detector Module Using a Dielectric-Waveguide-Integrated RTD,’’ EuMW 2026 (**accepted**).

Others

- Contribution to the deployment of LeapWave’s intelectual property (IP) strategy.

Thank you!
Questions?

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